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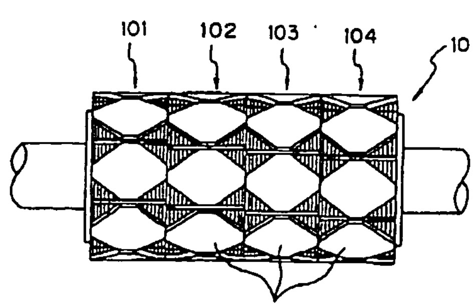
(54) STRUCTURE OF ROTOR OF SYNCHRONOUS MOTOR.

(57) A rotor (10) is divided into 2^n rotor elements (101, 102, 103, 104) to eliminate n kinds or the component (A, B) of the torque ripple of a synchronous motor. In order to eliminate the first component (A) of the torque ripple, the two rotor elements of each of 2^{n-1} rotor element pairs (101, 102; 103, 104) are shifted from each other by an angle corresponding to the half of the wavelength (λ) of the first component. In order to eliminate the second component (B), the 2^{n-1} rotor element pairs are divided into 2^{n-2} rotor element groups, each of which comprises the two pairs that are shifted from each other by an angle corresponding to the half of the wavelength (γ) of the second component. The shifting is repeated until the n-th torque ripple component is eliminated, thus constructing a rotor.

Fig. 1



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TECHNICAL FIELD

The present invention relates to a rotor structure of an electric synchronous motor, which is capable of cancelling a plurality of torque ripple components.

BACKGROUND ART

A conventional electric synchronous motor in which permanent magnets are used to construct a rotor thereof employs methods of reducing ripples in in output torque therefrom such as using a particular shaping of each of the permanent magnets or axially separating the rotor into a plurality of rotor components and arranging these rotor components to occupy one of two positions angularly displaced from one another about an axis of the rotor.

Nevertheless, the method of using a particular shaping of the permanent magnets is unable to completely cancel torque ripples from the output torque of the motor. Further, the method of arranging a plurality of rotor components of a synchronous motor at two angularly displaced positions foils to cancel all different torque ripples having respective different cycles, except for some specific torque ripples.

DISCLOSURE OF THE INVENTION

Accordingly, an object of the present invention in to provide a rotor structure of an electric synchronous motor, which is capable of cancelling a plurality of cyclic torque ripple components from an output torque of the motor.

In view of the above object of the invention, the present invention provides a structure of a permanent-magnet-included rotor for an electric synchronous motor generating an output torque containing therein "n" kinds of cyclic torque ripples, the rotor being divided into 2^n rotor elements having an equal longitudinal length respectively, these rotor elements being grouped into first through 2^{n-1}th pairs of rotor elements, and each pair of rotor elements including two rotor elements circumferentially shifted by an angle corresponding to a half of a wavelength of a first of the "n" kinds of torque ripple components, the 2^{n-1} pairs of said rotor elements being grouped into first through 2^{n-2}th rotor sections, each rotor section including two said rotor-element pairs arranged to be circumferentially shifted by an angle corresponding to a half of a wavelength of a second of the "n" kinds of torque ripple components, and in turn, said rotor elements being finally grouped into two groups of rotor elements, said two groups being arranged to be circumferentially shifted from one another by an angle corresponding to a half of a wavelength of "n"th of the "n" kinds of torque ripple components.

In accordance with the above rotor structure for an electric synchronous motor, the arrangement of the 2^{n-1} rotor-element pairs circumferentially shifted by an angle corresponding to the half of the first of the "n" kinds of torque ripple components contributes to a cancelling of said first of the "n" kinds of torque ripple components, and the arrangement of the first through 2^{n-2}th rotor sections further contributes to a cancelling of the second of the "n" kinds of torque ripple components, and in turn, the arrangement of the two groups of rotor elements finally contributes to a canceling of the "n"th of the "n" kinds of torque ripple components. Thus, the permanent magnet-included rotor for the synchronous motor initially must be manufactured to include 2^n rotor elements.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a front view of a rotor structure of an electric synchronous motor according to the present invention;

Fig. 2 is a schematic graphical view explaining an operation of the rotor structure of Fig. 1; and

Fig. 3 is a schematic graphical view explaining an operation of a rotor structure according to another embodiment of the present invention.

BEST MODE OF CARRYING OUT THE INVENTION

The present invention will become more apparent from the ensuing description of the embodiments of the present invention with reference to the accompanying drawings.

Referring to Fig. 1, a rotor 10 for an electric synchronous motor, having permanent magnets M, includes 2^2, i.e., four separate rotor elements 101, 102, 103 and 104 arranged to be at four stages from the left to the right in the longitudinal direction of the rotor and having an equal axial length, respectively, and capable of exhibiting an equal extent of a magnetic field, respectively. The illustrated embodiment of the rotor structure is able to cancel two kinds of torque ripple components from an output torque, i.e., a torque ripple component A having a wavelength "λ", and a torque ripple component B having a wavelength "γ".

The rotor elements 101 and 102 at the first and second stages form one pair of rotor elements for cancelling the torque ripple component A having the wavelength λ, and the rotor elements 103 and 104 at the third and fourth stages form another pair of rotor elements also for cancelling the torque ripple component A having the wavelength λ.

Namely, the rotor element 102 at the second stage is circumferentially shifted from the rotor element 101 at the first stage by a physical angle corresponding to a half of the wavelength λ, and the rotor element 104 at the fourth stage is circumferentially shifted from the rotor element 103 at the third stage by the same physical angle as the above-mentioned angle. As shown in Fig. 2, the torque ripples A1 and B1 appear in an output torque exerted from the rotor 10,and the torque ripples A2 and B2 appear in the output torque exerted from the rotor. It will be understood from the illustration of Fig. 2 that, since the latter torque ripples A2 and B2 have a displacement "λ/2" with respect to the former torque ripples A1 and B1, the torque ripple components A1 and A2 cancel one another out while the torque ripple components B1 and B2 having the wavelength γ are superimposed on one another to generate a different torque ripple B12, the wavelength of which is the same as that "γ" of the torque ripples B1 and B2, but the width of which is different from the torque ripple B1 or B2.

Further, a like canceling and superimposing of the torque ripple components of the output torque from the rotor 10 occurs with respect to the third and fourth stage rotor elements 103 and 104, as shown in Fig. 2. Namely, the torque ripple components A3 and A4 having a displacement "λ/2" cancel one another out, and the torque ripple components B3 and B4 are superimposed on one another to generate a different torque ripple component B34 having the same wavelength γ and width as those of the above-mentioned torque ripple component B12. Accordingly, when the first pair of rotor elements 101 and 102 and the second pair of rotor elements 103 and 104 are arranged to be circumferentially shifted from one another by a physical angle corresponding to a half of the wavelength γ of the torque ripple components B12 and B34, these torque ripple components B12 and B34 can cancel one another out, and consequently, two kinds of cyclic torque ripple components A and B can be completely removed from the output torque of the rotor.

Referring now to Fig. 3, another case is shown wherein three different torque ripple components A (the wavelength: λ), B (the wavelength: γ), and C (the wavelength: δ) contained in an output torque exerted from an electric synchronous motor are cancelled by a permanent-magnet included rotor structure of a synchronous motor according to a different embodiment of the present invention.

In this embodiment, the rotor is constructed by 2^3 equal rotor elements axially arranged side by side, in the same manner as in the embodiment of Fig. 1.

Similar to the embodiment of Fig. 2, the rotor of this embodiment has an arrangement such that first and second stage rotor elements constitute a first pair of rotor elements, the third and fourth stage rotor elements constitute a second pair of rotor elements, the fifth and sixth stage rotor elements constitute a third pair of rotor elements, and the seventh and eighth stage rotor elements constitute a fourth pair of rotor elements, and that the two rotor elements of each of the first through fourth pair of rotor elements are arranged to be circumferentially shifted around the axis of the rotor by a physical angle corresponding to "λ/2" so that cyclic torque ripple components A1 and A2, A3 and A4, A5 and A6, and A7 and A8 cancel one another out. Nevertheless, cyclic torque ripple components B12 and C12 having the wavelengths γ and δ still remain in an output torque exerted by the first pair of rotor elements of the rotor. Also, cyclic torque ripple components B34 and C34, B56 and C56, and B78 and C78 having the wavelengths γ and δ, respectively, remain in an output torque exerted by the second through fourth pairs of rotor elements of the rotor. At this stage, since the first pair of rotor elements including the first and second stage rotor elements and the second pair of rotor elements including the third and fourth stage rotor elements are circumferentially shifted around the axis of the rotor by a physical angle corresponding to a half of the wavelength "γ", i.e., γ/2, the torque ripple components B12 and B34 cancel one another out. Similarly, since the third pair of rotor elements including the fifth and sixth stage rotor elements and the fourth pair of rotor elements including the seventh and eighth stage rotor elements are circumferentially shifted around the axis of the rotor by the same physical angle as the above-mentioned angle "λ/2", the torque ripple components B56 and B78 having the wavelength λ cancel one another out. When the torque ripple component B is canceled, the cyclic torque ripple component C, i.e., the components C1234 and C5678 still remain in an output torque exerted by the rotor. At this stage, as a first section of rotor elements of the rotor including the first and second pairs of rotor elements, i.e., the first through fourth stage rotor elements and a second section of rotor elements of the rotor including the third and fourth pairs of rotor elements, i.e., fifth through eight stage rotor elements are circumferentially mutually shifted around the axis of the rotor by a physical angle corresponding to a half of the wavelength δ, i.e., δ/2, of the torque ripple component C, the torque ripple components C1234 and C5678 cancel one another out. Accordingly, all of the three kinds of torque ripples A, B and C appearing in the output torque exerted by the rotor of this embodiment can be cancelled.

When four or more cyclic torque ripples are contained in an output torque of a permanent-magnet included rotor of an electric synchronous motor, it is possible to cancel the torque ripples by applying the same shifting structure as those described above to the structure of a permanent-magnet included rotor for an electric synchronous motor.

From the foregoing description, it will be understood that, in accordance with the present invention, a rotor structure for an electric synchronous motor can cancel a plurality of kinds of cyclic torque ripples from an output torque of the motor.

LIST OF REFERENCE NUMERALS AND ELEMENTS

10:	rotor element
A1-A8:	torque ripple component having a wavelength λ
B1-B8:	torque ripple component having a wavelength γ
C1-C8:	torque ripple component having a wavelength δ
M:	magnet

Claims

1. A structure of a permanent-magnet-included rotor for an electric synchronous motor generating an output torque containing therein "n" kinds of cyclic torque ripples, characterized in that

   said rotor is divided into 2^n rotor elements having an equal longitudinal length, respectively, these rotor elements being grouped into first through 2^{n-1}th pairs of rotor elements, each pair of rotor elements including two rotor elements circumferentially shifted by an angle corresponding to a half of a wavelength of a first of the "n" kinds of torque ripple components, said 2^{n-1} pairs of said rotor elements being grouped into first through 2^{n-2}th rotor sections, each rotor section including two said rotor-element pairs arranged to be circumferentially shifted by an angle corresponding to a half of a wavelength of a second of said "n" kinds of torque ripple components, and in turn, said rotor elements being finally grouped into two groups of rotor elements, said two groups being arranged to be circumferentially shifted from one another by an angle corresponding to a half of a wavelength of "n"th of the "n" kinds of torque ripple components.

Fig. 1

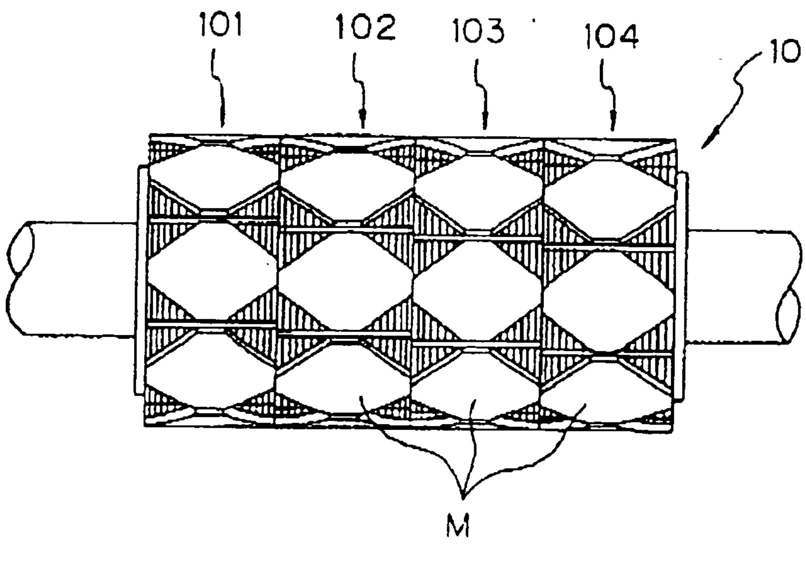
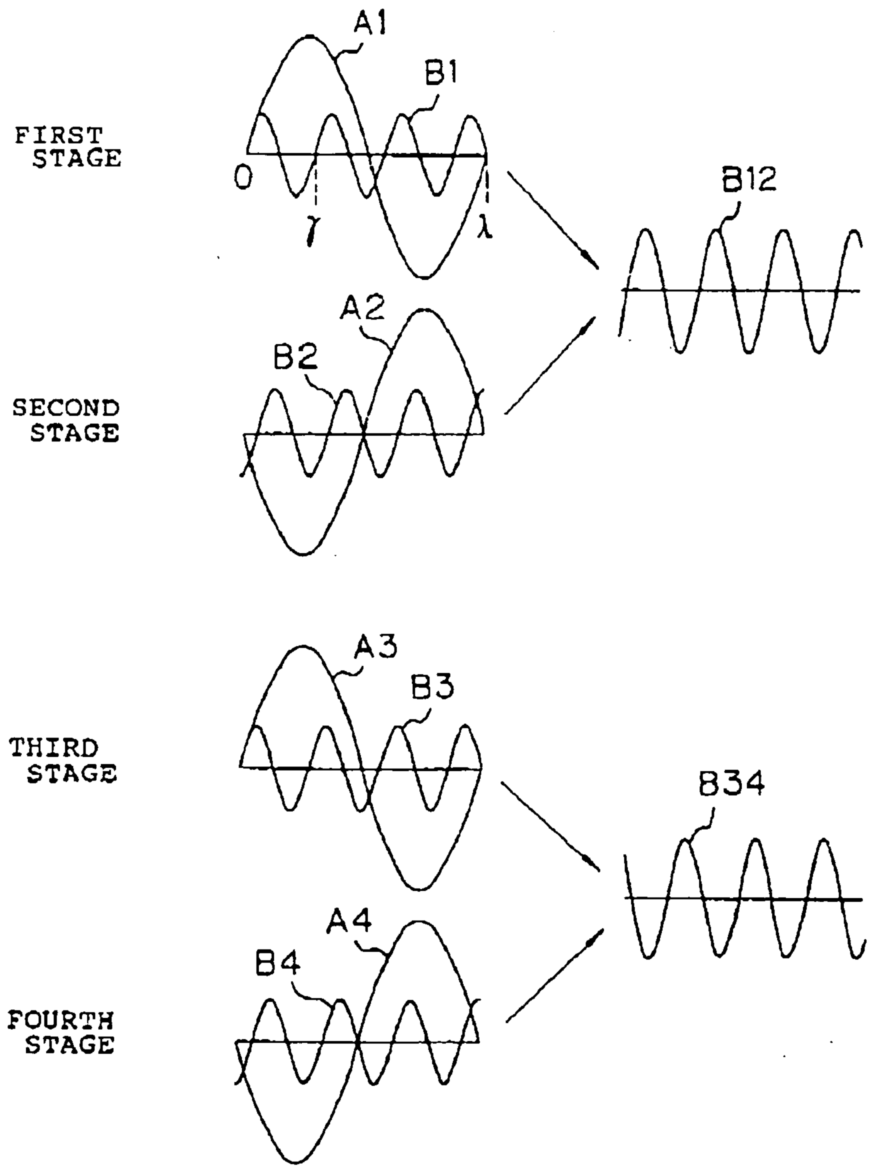


Fig. 2


FIRST STAGE
SECOND STAGE
THIRD STAGE
FOURTH STAGE
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γ
λ
A2
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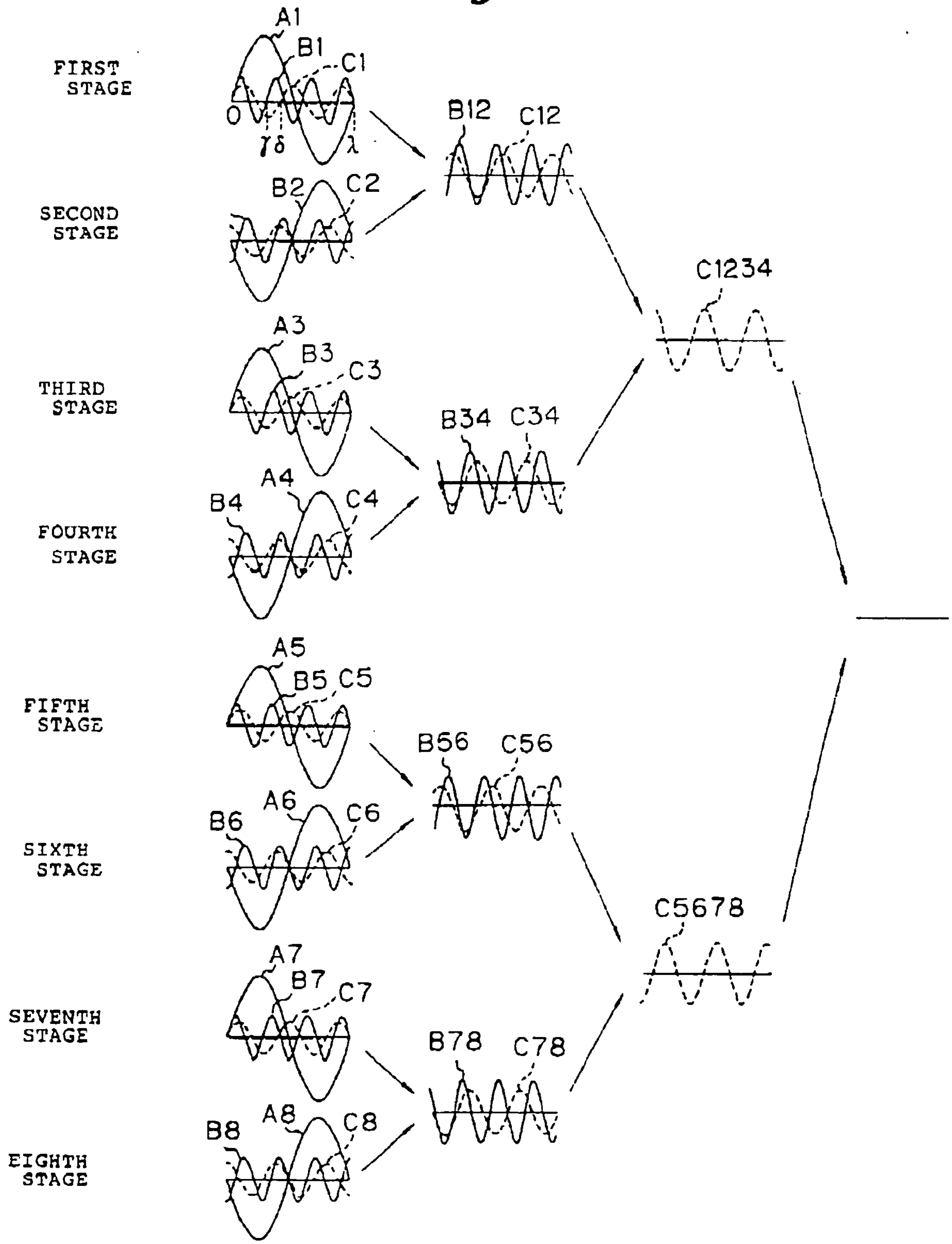
B34

FIg. 3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FIFTH STAGE
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B5
C5
SIXTH STAGE
B6
A6
C6
SEVENTH STAGE
A7
B7
C7
EIGHTH STAGE
B8
A8
C8
B12
C12
B34
C34
B56
C56
B78
C78
C1234
C5678

INTERNATIONAL SEARCH REPORT

International Application No PCT/JP91/00640

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) [6]

According to International Patent Classification (IPC) or to both National Classification and IPC

Int. Cl^5 H02K1/27, 501

II. FIELDS SEARCHED

Minimum Documentation Searched [7]

Classification System	Classification Symbols
IPC	H02K1/00

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched [8]

Jitsuyo Shinan Koho	1926 - 1991
Kokai Jitsuyo Shinan Koho	1971 - 1991

III. DOCUMENTS CONSIDERED TO BE RELEVANT [9]

Category [*]	Citation of Document, [11] with indication, where appropriate, of the relevant passages [12]	Relevant to Claim No. [13]
Y	JP, A, 62-239851 (Nippon Denki Seiki K.K.), October 20, 1987 (20. 10. 87) & US, A, 4865432	1
A	JP, A, 63-140645 (Fuji Electric Co., Ltd.), June 13, 1988 (13. 06. 88), (Family: none)	1
A	JP, A, 60-66657 (Hitachi, Ltd.), April 16, 1985 (16. 04. 85), (Family: none)	1
A	JP, U, 63-124072 (Mitsubishi Electric Corp.), August 12, 1988 (12. 08. 88), (Family: none)	1

* Special categories of cited documents: [10]

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IV. CERTIFICATION

Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report
July 25, 1991 (25. 07. 91)	August 12, 1991 (12. 08. 91)
International Searching Authority	**Signature of Authorized Officer**
Japanese Patent Office	